CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-202
DEEP SPRINGS FAULT ZONE,
NORTHERN INYO COUNTY, CALIFORNIA

by

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INTRODUCTION

Potentially active faults in northern Inyo County that are evaluated in this Fault Evaluation Report (FER) include faults that comprise the Deep Springs fault zone (Figure 1). The Deep Springs Valley study area is located in parts of the Waucoba Mtn., Blanco Mountain, and Soldier Pass 15-minute quadrangles (Figure 1). Traces of the Deep Springs fault zone in the Deep Springs Valley study area are evaluated as part of a statewide effort to evaluate faults for recency of activity. Those faults determined to be sufficiently active and well-defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act of 1972 (Hart, 1985).

SUMMARY OF AVAILABLE DATA

The Deep Springs Valley study area is located in Deep Springs Valley, a northeast-trending closed basin (graben) at the southern end of the White Mountains (Figure 1). The study area is located in the western part of the Basin and Range geomorphic province and is characterized by oblique Basin and Range extensional tectonics which results in both normal and right-lateral faulting along north to northwest-trending faults.

Topography in the study area ranges from the flat playa surface of Deep Springs Lake to the extremely rugged west-northwest-facing slopes that form the southeast side of Deep Springs Valley. Elevations in the study area range from 1524 meters to approximately 2440 meters above sea level. Development in the study area is low and most of the area is used for agricultural purposes. Deep Springs Junior College, located near the northern end of the valley, is the only settlement in the valley.

Rocks types in the study area include Paleozoic metasedimentary and sedimentary rocks, Mesozoic plutonic rocks (mainly granitic), minor Tertiary volcanic rocks, and Quaternary alluvial deposits (Nelson, 1966a, 1966b; McKee and Nelson, 1967; Strand, 1967; Lustig, 1965). Quaternary deposits include late Pleistocene and Holocene alluvial fan and lacustrine deposits.

DEEP SPRINGS FAULT ZONE

The Deep Springs fault is a normal fault with down-to-the-west displacement that forms the eastern boundary of Deep Springs Valley, a 24 km-long north-northeast trending graben. Wilson (1975) reported that the Deep Springs fault dips about 40o to the west and offsets basement rocks west of the range front as much as 792 meters, based on magnetic, gravity, and seismic refraction surveys. The maximum cumulative vertical displacement along the Deep Springs fault may total as much as 1523 meters, based on this geophysical evidence and the 731 meter-high escarpment (Wilson, 1975).

Miller (1928) first named the Deep Springs fault. Miller reported that displacement along the Deep Springs fault was more recent than displacement along the unnamed fault zone bounding the west side of Deep Springs Valley (Figure 1), based on the rugged terrain, the distribution of alluvial fans, and the "great triangular facets" that delineate the Deep Springs fault. Miller postulated that up to 60 meters of displacement has occurred along the Deep Springs fault since formation of Pleistocene Deep Springs Lake, based on the 60 meter uplift of the drainage through Soldier Pass, the occurrence of old lake beds at the same elevation as the drainage channel, and the presence of probable Pleistocene sediments in the Soldier Pass drainage. Miller concluded that this channel once connected Deep Springs Valley with Eureka Valley to the east.

Mapping that will be evaluated in this FER includes Nelson (1966a and 1966b) and McKee and Nelson (1967) (Figure 2). Both Nelson (1966a and 1966b) and McKee and Nelson (1967) did not differentiate between Pleistocene and Holocene alluvial units, combining all units under Quaternary age deposits. However, it is assumed that units Qvf, Qf, and Qa are the youngest units mapped by both Nelson and McKee and Nelson and are probably latest Pleistocene and Holocene in age. The Deep Springs fault will be discussed from south to north.

The southern extent of the Deep Springs fault extends onto the NE 1/4 of the Waucoba Mtn. 15-minute quadrangle and was mapped by Nelson (1966a) (shown in orange, Figure 2) as mostly concealed by Qf deposits . Locally, strands of the Deep Springs fault juxtapose Paleozoic bedrock against young alluvium and Nelson mapped young alluvium as offset at locality 1 (Figure 2). The Deep Springs fault mapped by Nelson south of Deep Springs Valley primarily offsets Paleozoic metasedimentary rocks and is concealed by young alluvium and, locally, by Pleistocene older alluvium (Figure 2).

Nelson (1966b) mapped the Deep Springs fault in the SE 1/4 of the Blanco Mountain 15-minute quadrangle (shown in red-brown, Figure 2). Nelson mapped most strands of the Deep Springs fault as offsetting his Qf alluvial unit, which is presumed to be latest Pleistocene and Holocene (Figure 2). The Deep Springs fault mapped by Nelson is delineated by predominantly west-facing scarps in alluvium, although minor grabens are mapped locally (locality 2, Figure 2).

The Deep Springs fault in the Soldier Pass 15-minute quadrangle was mapped by McKee and Nelson (1967) (shown in blue-green, Figure 2). Most traces of the Deep Springs fault mapped by McKee and Nelson offset their Qf unit (Figure 2). The Deep Springs fault is depicted as a down-to-the-west normal fault delineated primarily by west-facing scarps in alluvium (Figure 2). At the northern end of Deep Springs Valley the Deep Springs fault splays and changes to a more easterly trend, locally offsetting Quaternary alluvium (locality 3, Figure 2). The Deep Springs fault approaches to within 5 km of the Fish Lake Valley branch of the Northern Death Valley-Furnace Creek fault zone north of Deep Springs Valley (see FER-193, Bryant, 1988), becoming complex and distributive (Figures 1 and 2).

Faults along the west side of Deep Springs Valley (Figure 1, not plotted on Figure 2) mapped by Nelson (1966a) and McKee and Nelson (1967) do not offset Pleistocene alluvium and are not evaluated in this FER.

FAULT IN NORTHWESTERN EUREKA VALLEY

McKee and Nelson (1967) mapped a short (2.5 km), northeast-trending fault in the northwestern part of Eureka Valley (locality 18, Figure 2). This northeast-trending fault offsets their Qf alluvial and Ql lacustrine units, and is delineated by both northwest and southeast-facing scarps (Figure 2). Although this short fault is not associated with the Deep Springs fault zone, it is located in the southwest quarter of the Soldier Pass 15-minute quadrangle and is evaluated along with the Deep Springs fault zone.

INTERPRETATION OF AERIAL PHOTOGRAPHS AND FIELD OBSERVATIONS

Aerial photographic interpretation by this writer of faults in the Deep Springs Valley study area was accomplished using U.S. Bureau of Land Management (1975) (CMOOO, approximate scale 1:26,500) and U.S. Geological Survey (1982, GS-VFDT, approximate scale 1:26,000) aerial photographs.

Approximately 2 days were spent in the field in August 1988 by this writer. Selected fault traces were verified and subtle features not observable on the aerial photographs were mapped in the field. The age of offset geomorphic surfaces was estimated by observing soil profile development and preservation of constructional surfaces (rock varnish, desert pavement, boulder weathering). Results of aerial photographic interpretation and field observations by this writer are summarized on Figure 3.

Fault scarp heights and scarp-slope angles were measured in order to estimate recency of faulting, based on the work of Wallace (1977). A direct correlation between the ages indicated by fault scarp profiles measured by Wallace (1977) in Nevada and scarp profiles measured during investigations for this FER cannot be made due to different lithology, climate, and style of faulting (Mayer, 1982). However, the data presented by Wallace (1977, 1978) can be used as a guide (or additional factor) when evaluating the geomorphic features and age of offset deposits (when known) for recency of faulting. Some very general guidelines for estimating scarp ages are summarized as follows. Fault scarp angles for faults in unconsolidated alluvium and colluvium no older than 10,000 to 12,000 yrs BP can range from 10° to 35° (Wallace, 1977). The average scarp angle is about 22°, based on Figure 8 of Wallace (1977), although Figure 12 of Wallace (1977) indicates that scarp angles of about 19° represent minimum Holocene age. The scarp crest width for scarps no older than about 10,000 yrs BP ranges from 1 to about 6 meters (Wallace, 1977, Figure 11). Wide variations occur, but these figures probably represent minimum criteria suggesting Holocene displacement.

In addition, fault scarp profiles were measured across selected fault strands in order to calculate the morphologic age of the scarps using the computer program of Nash (1986, 1987). In order to determine the morphologic age of a scarp (t=time of degradation of original configuration of scarp), it is necessary to determine the rate of erosional degradation, the diffusivity constant c. In the Waucoba Mtn. study area the value for c is unknown. However, studies by Hanks and Wallace (1986) have determined that the value c = 0.001m2/yr. seems to be consistent throughout the Great Basin. Therefore, c=0.001m2/yr will be used for morphologic age calculations in this FER. However, values for t derived in this FER should be considered to be preliminary.

DEEP SPRINGS FAULT ZONE

Traces of the Deep Springs fault zone are generally well-defined throughout most of the study area (Figure 3). Mapping by Nelson (1966a and 1966b) and McKee and Nelson (1967) was mostly verified by this writer, although differences in detail and location occur (Figures 2 and 3).

The southern extent of the Deep Springs fault zone in the NE 1/4 of the Waucoba Mtn. 15-minute quadrangle south of locality 1 (Figures 2 and 3) is moderately defined, but lacks geomorphic evidence of latest Pleistocene and Holocene normal displacement. However, a well-defined west-facing scarp in Holocene alluvium at and north of locality 1 demonstrates Holocene displacement along a part of the Deep Springs fault zone in the NE 1/4 of the Waucoba Mtn. quadrangle. The southern extent of the Deep Springs fault zone in the NE 1/4 of the Waucoba Mtn. 15-minute quadrangle south of locality 1 (Figures 2 and 3) is moderately defined, but lacks geomorphic evidence of latest Pleistocene and Holocene normal displacement. However, a well-defined west-facing scarp in Holocene alluvium at and north of locality 1 demonstrates Holocene displacement along a part of the Deep Springs fault zone in the NE 1/4 of the Waucoba Mtn. quadrangle.

The Deep Springs fault zone in the Blanco Mountain and Soldier Pass 15-minute quadrangles is delineated by abundant geomorphic evidence of Holocene normal faulting, such as well-defined scarps in latest Pleistocene and Holocene alluvial fans, closed depressions, and vertically offset drainages (localities 4-11, Figure 3). Geomorphic evidence of a component of left-lateral strike-slip displacement, which is suggested by the northeastern orientation of the Deep Springs fault, was not observed by this writer.

North of Deep Springs Valley, the Deep Springs fault is much less well-defined and becomes distributive (Figure

3). The Northern Death Valley-Furnace Creek fault zone, located about 5 km northeast of Deep Springs Valley (Figure 1), may influence the distributive pattern of the northern Deep Springs fault. Minor, moderately well-defined scarps in late Quaternary alluvium locally delineate traces of the Deep Springs fault. A moderately defined, northeast-trending fault in bedrock may continue to the northeast, but geomorphic evidence of recent faulting was not observed by this writer (locality 16, Figure 3).

A well-defined, northwest-trending lineament was mapped by this writer at locality 17 (Figure 3). This 1.3 km-long lineament, which was not mapped by Nelson (1966b), is delineated by a northeast-facing scarp in Holocene alluvium, right-laterally deflected drainages, and tonal lineaments (vegetation contrasts). This lineament could possibly be a remnant shoreline, but the scarp is facing the opposite way one would expect for a wave-cut bench. Right-lateral strike-slip faulting is compatible with the orientation of this feature. Additional northwest-trending lineaments in Deep Springs Valley were not observed.

Alluvial fans along the west side of Deep Springs Valley are much larger than the alluvial fans along the east side of the valley. The configuration of the alluvial fans on both the east and west sides of Deep Springs Valley indicate: 1) eastward tilting of Deep Springs Valley and 2) inactivity of faults bounding the west side of Deep Springs Valley, perhaps since mid to late Pleistocene time.

The nature of the alluvial fans along the east side of Deep Springs Valley varies from south to north. In the southeastern part of Deep Springs Valley the alluvial fans generally are extremely coarse and consist of boulder-sized clasts of metasedimetary rocks and granitic rocks at the southernmost end of Deep Springs Valley and fresh granitic boulders north of locality 12 (Figure 3). Most of the alluvial fans that consist predominantly of granitic boulders between localities 8 and 12 have very little sand and silt sized components. Alluvial fans are significantly less coarse north of locality 15 (Figure 3) and consist of coarse gravelly sand derived from granitic rocks with occasional boulders to 1 meter in diameter. Soils developed on the northern fan surfaces are poorly developed, generally consisting of A-C profiles. Fan surface morphology consists of moderately preserved constructional surfaces, poorly developed to no desert pavement, and incipient rock varnish.

Fault scarp profiles at localities 7 and 10 (Figure 3) are shown in Table 1. Morphologic ages for the scarps profiled all indicate a mid-to-late Holocene age for scarps. The morphologic ages are consistent with additional geomorphic evidence of Holocene displacement, such as closed depressions and vertically offset drainages (Figure 3). Additional fault scarp profiles all strongly indicate Holocene displacement (e.g. localities 6, 8, 13, 14, Figure 3). The tc value derived from scarps in the northern part of Deep Springs Valley (Profile DS02, Table 1) suggests that the scarp is somewhat older than the scarp profiled in the southern end of the valley. This may be true because there seems to be a right step of the fault zone near locality 15 (Figure 3), which suggests possible segmentation of the Deep Springs fault zone. Thus, late Quaternary slip-rates may be greater along the southern part of the Deep Springs fault. However, the different compositions of the alluvial fans north and south of locality 15 may contribute to the rate of degradation of the fault scarps, perhaps yielding an erroneously greater morphologic age for scarps developed in the finer-grained alluvial fans north of locality 15.

The high stand of Deep Springs Lake is reported to be at about the 1585-meter contour. It is possible that shoreline erosion could have modified or enhanced the well-defined west-facing scarps that delineate traces of the Deep Springs fault zone. However, most fault scarps that delineate traces of the Deep Springs fault locally cross topographic contours and could not have formed or been enhanced by wave erosion (Photo 1; Figure 3). In addition, alluvial fan surfaces that are offset have no evidence of wave-cut benches.

The nature of displacement of some of the young alluvial fans east of Deep Springs Lake is unusual (Figure 3). Scarp heights in alluvium are as great as 20 meters, yet the displacement is apparently mostly extensional rather than vertical. This is based on the apparent lack of vertical separation when the slope of the alluvial fan is projected westward to the other side of the graben. The width of the graben is approximately 35 meters near locality 4 (Figure 3). The style of displacement observed at locality 4 was not observed elsewhere along the Deep Springs fault zone (Figure 3). Low, arcuate ridges east of locality 4 may be related to this local style of displacement, although this is speculative.

FAULT IN NORTHWESTERN EUREKA VALLEY

The northeast-trending fault in northwestern Eureka Valley mapped by McKee and Nelson (1967) is moderately to poorly defined, based on air photo interpretation by this writer (locality 18, Figure 2). The southwestern part of the fault offsets older Pleistocene alluvium and lacustrine deposits and is delineated by a moderately defined, subdued northwest-facing scarp. This scarp is partly buried by young (Holocene ?) alluvium. To the northeast the fault mapped by McKee and Nelson is poorly defined and is concealed by latest Pleistocene to Holocene alluvium. This fault was not verified as a well-defined, recently active fault by this writer (locality 18, Figure 2).

SEISMICITY

Seismicity in the Deep Springs Valley study area is depicted in Figure 4. A and B quality epicenter locations by California Institute of Technology (1985) and University of Nevada, Reno (1985) are for the period 1932 to 1985.

Seismicity in the Deep Springs Valley study area is relatively quiescent (Figure 4). A few scattered epicenters located at the northeastern end of Deep Springs Valley may be associated with the Deep Springs fault zone, but distinctive patterns of seismicity that can be directly related to specific fault traces are not present (Figure 4).

CONCLUSIONS

DEEP SPRINGS FAULT ZONE

The Deep Springs fault zone is a north-northeast trending zone of normal faults with down-to-the-west vertical displacement that may total as much as 1523 meters (Wilson, 1975). Traces of the Deep Springs fault zone mapped by Nelson (1966a and 1966b) and McKee and Nelson (1967) are delineated by west-facing scarps in young alluvium.

The Deep Springs fault zone in the Deep Springs Valley study area is generally very well-defined and is delineated by abundant geomorphic evidence of Holocene normal displacement, based on air photo interpretation and field inspection by this writer (localities 4-11, 13 and 14, Figure 3). The Deep Springs fault zone offsets young alluvial fans that are latest Pleistocene and Holocene age, based on poorly developed soil horizons and the relative freshness of alluvial fan constructional surfaces (Figure 3). Fault scarp profiles further indicate Holocene displacement along most of the Deep Springs fault zone (localities 7, 8, 10, and 13, Figure 3, Table 1).

The Deep Springs fault zone south of locality 1 (Figures 2 and 3) and northeast of locality 16 (Figure 3) is only moderately defined and is not delineated by geomorphic evidence of latest Pleistocene and Holocene displacement. There is a small section of the Deep Springs fault zone north of locality 1 in the Waucoba Mtn. 15-minute quadrangle that is well-defined and has geomorphic evidence of Holocene displacement. However, only a very small part of this fault trace is located in the Waucoba Mtn. quadrangle (~ 0.8 km) and the area is extremely remote and generally inaccessible.

The northwest-trending lineament at locality 17, delineated by a well-defined, northeast-facing scarp in Holocene alluvium and two right-laterally deflected drainages, is probably fault-related (Figure 3). Alternatively, this feature could be a wave-cut scarp, but the scarp faces in the opposite direction that one would anticipate for a wave-cut feature.

FAULT IN NORTHWESTERN EUREKA VALLEY

The northeast-trending fault mapped by McKee and Nelson (1967) in the northwestern part of Eureka Valley is moderately to poorly defined and does not offset latest Pleistocene to Holocene alluvium (locality 18, Figure 2). The trace mapped by McKee and Nelson was only partly verified by this writer and does not seem to be sufficiently active.

RECOMMENDATIONS

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well-defined" (Hart, 1985).

DEEP SPRINGS FAULT ZONE

Zone for special studies well-defined traces of the Deep Springs fault zone mapped by Nelson (1966b), McKee and

Nelson (1967), and Bryant (this report) as depicted in Figures 2 and 3 (highlighted in yellow). Principal references cited should be Nelson (1966b), McKee and Nelson (1967), and Bryant (this report).

Do not zone traces of the Deep Springs fault zone in the NE 1/4 of the Waucoba Mtn. 15-minute quadrangle at this time. This area is extremely remote, relatively inaccessible, and zoning such a small area is not warranted at this time. However, a note should be placed at the southeast end of the Blanco Mountain quadrangle stating that active faults may continue to the southeast.

FAULT IN NORTHWESTERN EUREKA VALLEY

Do not zone for special studies the northeast-trending fault mapped by McKee and Nelson (1967) (locality 18, Figure 2). This fault is only 2.5 km long, is moderately defined, and is not sufficiently active.

Report and air photos reviewed; recommendations approved. Earl W. Hart 1/18/89

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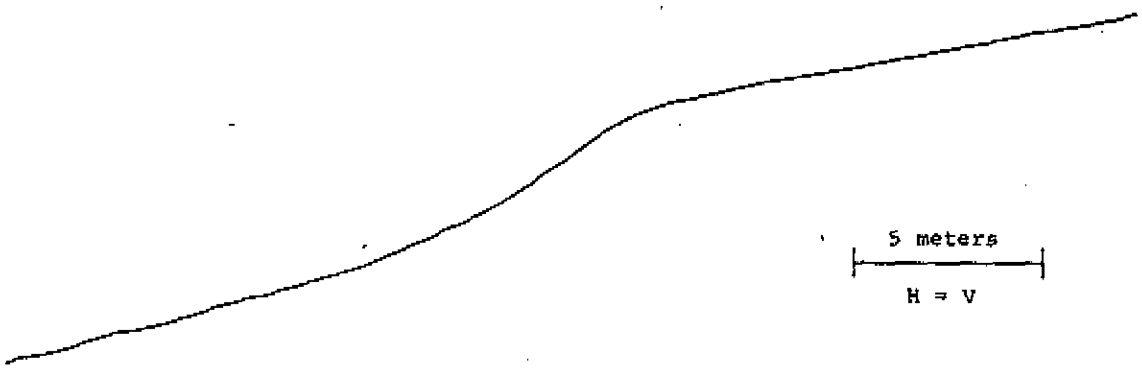
TABLE 1-MORPHOLOGIC DATING OF SELECTED SCARPS

(after Nash, 1987)

<u>Profile DS01</u> (locality 7, Figure 3)



height[1] = 4.85 m
$\measuredangle$[1] = 35^{o}
crest[1] = 2.2 m

tc = 2.05 m^2

assume c[2] = 0.001 m^2/yr
t[3] = 2050 yr

<u>Profile DS02</u> (locality 10, Figure 3)

height[1] = 4.9 m
$\measuredangle$[1] = 27^{o}
crest[1] = 2.8 m

tc = 4.55 m^2

assume c[2] = 0.001 m^2/yr
t[3] = 4558 yr

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1 scarp parameters from Wallace (1977); see Figure 3 for explanation
2 rate of erosional degradation (diffusivity constant)
3 time of degradation of original configuration of scarp

Photo 1 (to FER-202). View east-southeast of the Deep Springs fault near locality 7 (Figure 3). The fault at this location is delineated by a well-defined scarp located near the base of the mountain front (arrows). Faceted spurs and vertically offset or incised drainages are associated with this west-facing scarp. Scarp profile DS01 (Table 1; locality 7, Figure 3) was measured on the Holocene alluvial fan indicated by the open arrow.

Photo 2 (to FER-202). View east of the southern end of Deep Springs Valley, showing well-defined scarps in alluvial fans that delineate the Deep Springs fault near locality 4 (Figure 3).